United States Environmental Protection Agency

Modeling Mercury Exposure at Different Scales in the McTier Creek Watershed and Edisto River Basin, SC, USA

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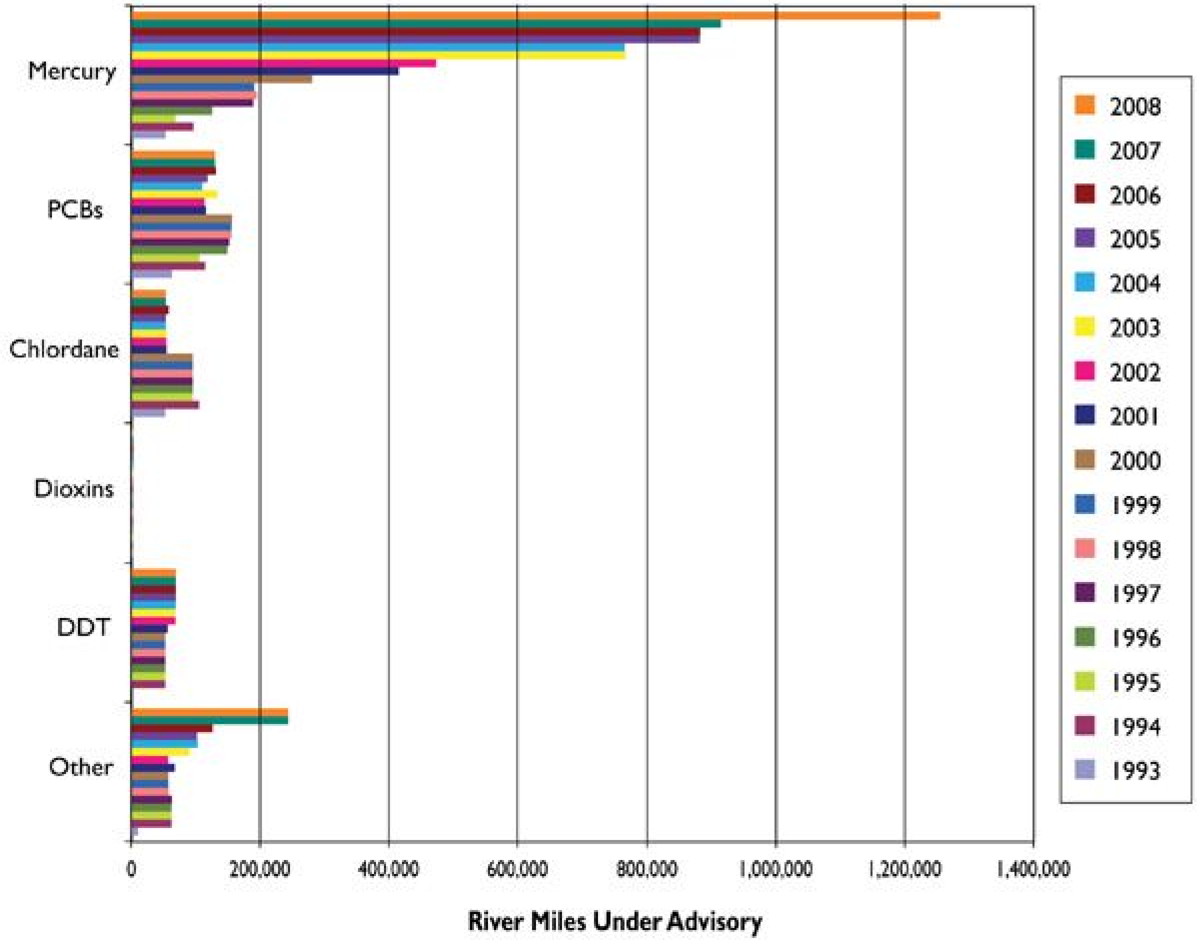
Water: One Resource – Shared Effort – Common Future
Eighth National Monitoring Conference
April 30 – May 4, 2012 ● Portland, Oregon

Presentation Outline

- Research Background
- Research Motivation
- Goal and Questions
- Research Approach
- Results
- Parallel Research and Future Work

Research Background

- In the USA as of 2008
  - 50 states, 1 US territory, and 3 tribes have Hg fish advisories
  - 80% of all fish advisories in US surface waters are at least partially due to mercury
  - 68,000 km^2 of lakes
  - 2,100,000 km of rivers

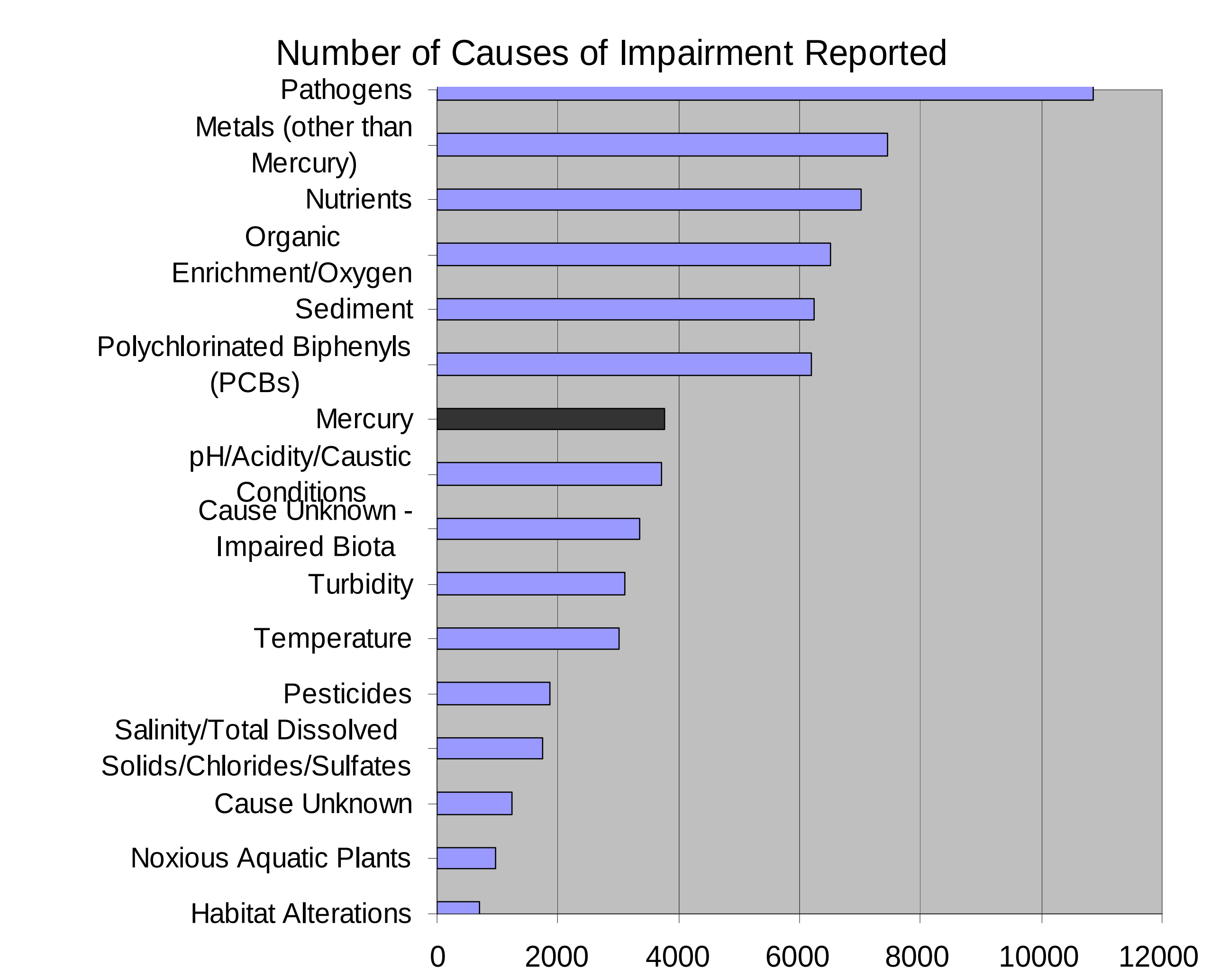


US Clean Water Act Section 303(d)

"to restore and maintain the chemical, physical, and biological integrity of the Nation's waters"

Law requires states develop a list of impaired waters and develop TMDLs for identified waters

Almost 4,000 waters in the US require Hg TMDLs



Research Motivation

- 80% of all fish advisories in US surface waters are at least partially due to Hg
- > 2,000,000 km of rivers have Hg fish consumption advisories
- Almost 4,000 water bodies are listed on State Clean Water Act Section 303(d) as impaired due to Hg, triggering the development and implementation of Total Maximum Daily Loads (TMDLs) for Hg
- Hg comes from a variety of sources, all of these sources must be accounted for in the TMDL process
- Streams and Rivers are intimately linked with their watersheds and incorporating out-of-channel processes and loading sources is critical to understanding Hg exposure

Overall Research Goals

Understand and minimize mercury exposure to wildlife and humans by improving the understanding of mercury fate and transport in watersheds and surface waters

Research Questions

- What processes and factors govern mercury exposure concentrations in streams and rivers
- How can we better inform the development of mercury TMDLs that are often developed for large basins (series of 8 digit HUCs)
- How can we use mechanistic, differential mass-balance models to better understand mercury fate and transport in
  - Streams
  - Rivers
  - Headwater watersheds
  - Regional Basins
- How can we scale up detailed research studies to understand mercury exposure at larger scales and better understand impacts of management strategies

Research Approach

- Use mechanistic, differential mass balance models to simulate the fate and transport of mercury.
- Use multiple scales of models to investigate processes at different scales
- Use focused reach study to inform sub-basin and basin watershed modeling of Hg
- Use watershed model to inform spatially explicit regional basin

Research Approach: Mechanistic Models

Spatially and temporally explicit mechanistic, differential mass balance model

- *Watershed Model: Visualizing Ecosystems for Land Management Assessment for Hg (VELMA-Hg) (see poster session)*
  - Simulates
    - Hydrology (Runoff, subsurface for 4 soil layers)
    - Carbon: Dissolved Organic and Soil Organic
    - Nitrogen: Ammonium, Nitrate, Dissolved Organic
    - Mercury: MeHg, Hg(II)
    - Processes: methylation, demethylation, reduction/evasion

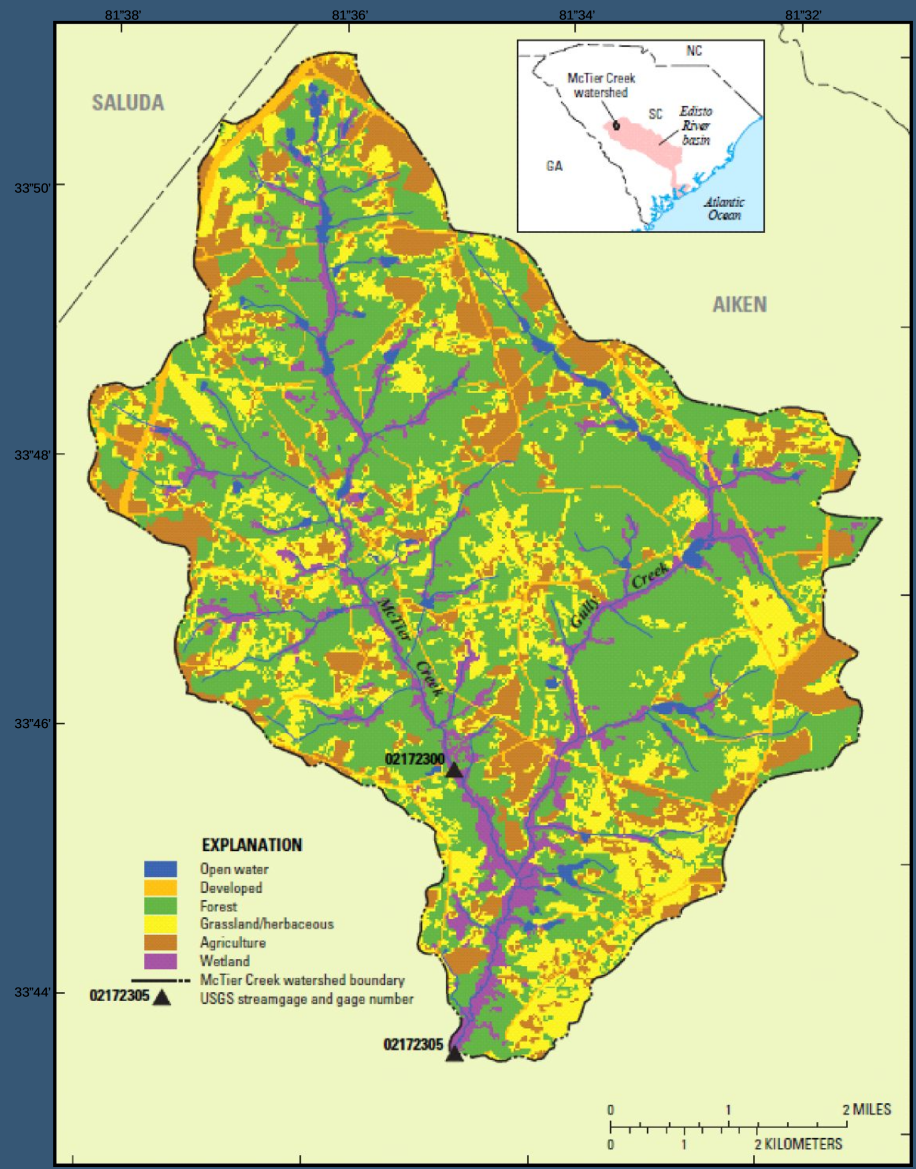
Study Site: McTier Creek Watershed, SC, US

- Sand Hills region of Upper Coastal Plain, SC

- 79 km^2 drainage area

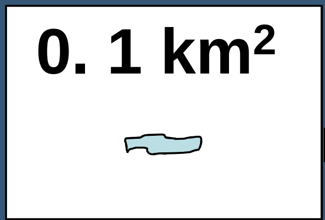
- Mixed land cover: 49% forest, 21% grassland and herbaceous, 16% agriculture, 8% wetland, 5% developed, 1% open water

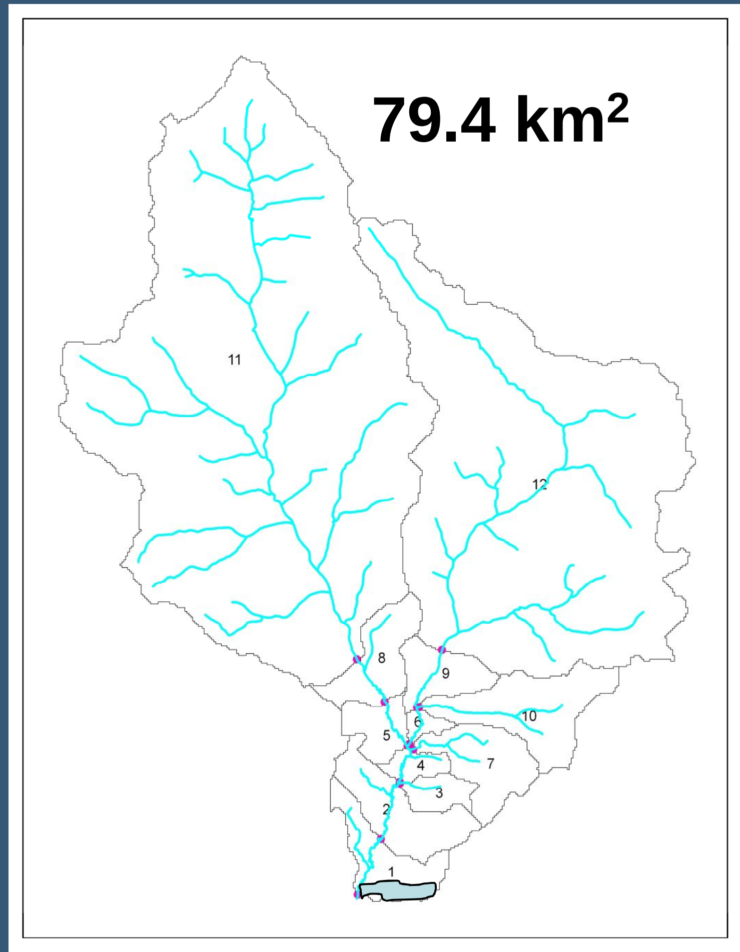
- Shallow groundwater system
  - o Low – normal flow: toward stream channel
  - o High flow: same with increased area of groundwater-surface water exchange



Land-cover data from 2001
National Land-Cover Dataset (Homer and others, 2004)
Albers projection, NAD 83 datum,
Central Meridian - 95 00 00

Research Approach: Modeling Range of Scales





Focused Reach → sub-watershed → watershed

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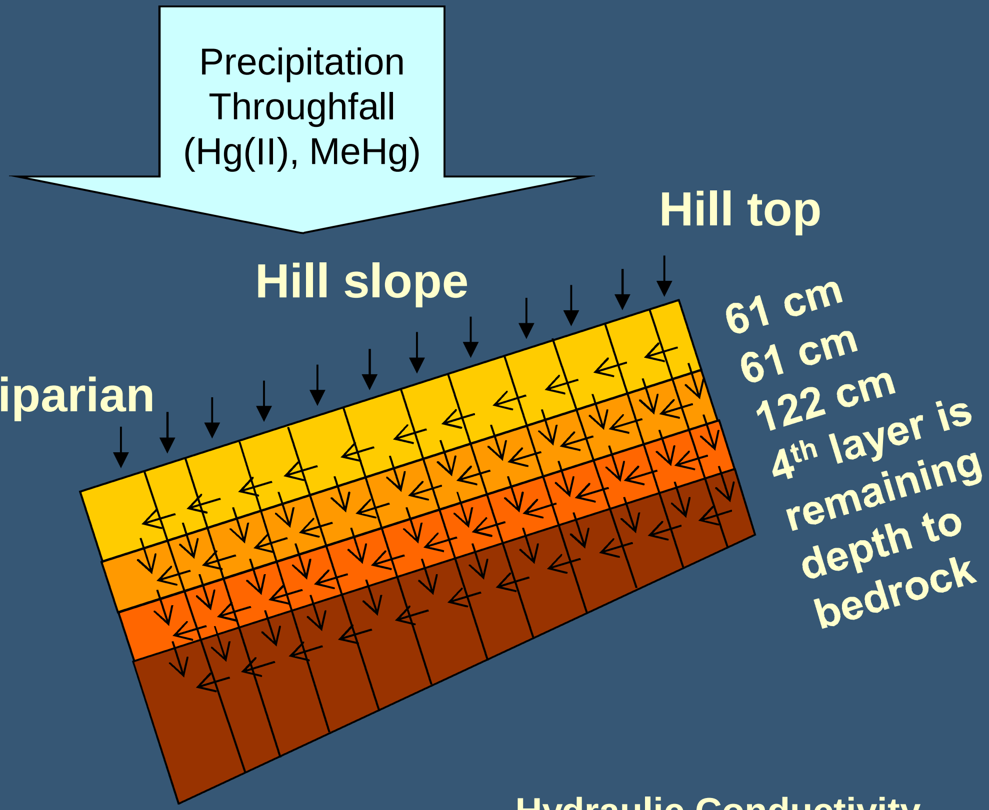
Focused Reach Study:



Sampling

- HgT and MeHg concentrations in soil
- Sampled at different depths
- Provides spatial snapshot of Hg concentrations

Modeling

- VELMA watershed model
- Calibrated rate constants using observed data
- Simulates soil concentrations
    - (Hg, N, C)
- Output: Q, Hg(II) and MeHg

Hydraulic Conductivity

	Vertical	Lateral
Layer 1	4.4 m/d	4.1 m/d
Layer 2	2.0 m/d	0.1 m/d
Layer 3	3.2 m/d	4.1 m/d
Layer 4	0.16 m/d	0.074 m/d

Focused Reach Study: Methylation/Demethylation

$$\text{Methylation Rate} = k_m \times [Hg(II)] \times Q_{10,m}^{(Tm-20)} \times \text{Soil Saturation}$$

$$\text{Demethylation Rate} = k_d \times [MeHg] \times Q_{10,d}^{(Td-20)} \times \text{Soil Saturation}$$

Rate Constant	Zone	Layer	Value
k_m	Riparian, uplands	All	0.007 d^{-1}
	Wetlands	All	0.01 d^{-1}
k_d	All	Layers 1,2,4	0.015 d^{-1}
	All	3	0.03 d^{-1}
$Q_{10,m}$	All	All	1.14
$Q_{10,d}$	All	All	1.04
T_m	All	All	15
T_d	All	All	22

Laboratory and field study being used to parameterize constants

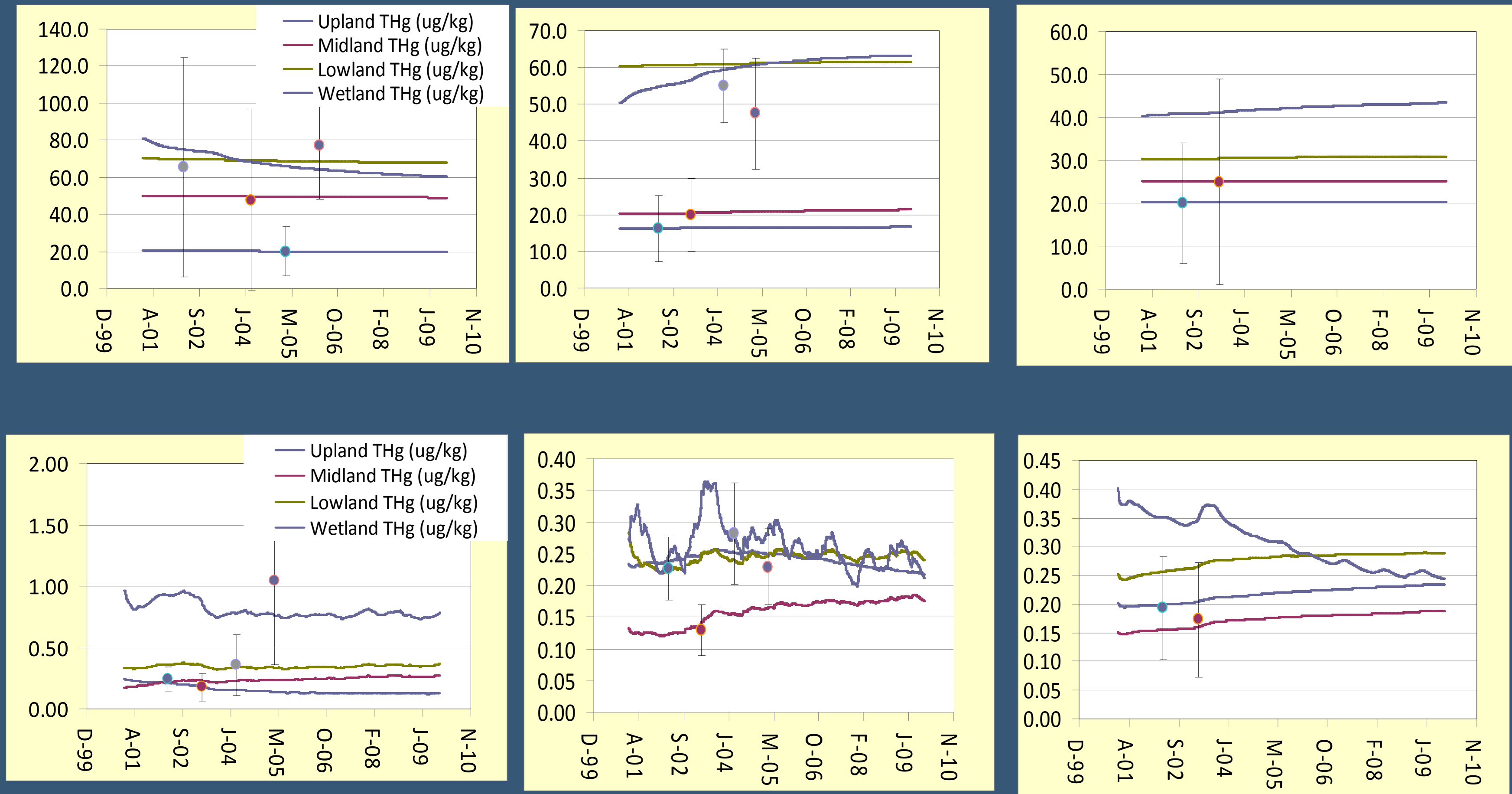
Comparing observed stream concentrations and soil concentrations for evaluation

Focused Reach Study: Soil Mercury Concentrations and Simulations

Layer 1 | Layer 2 | Layer 3

HgT

MeHg



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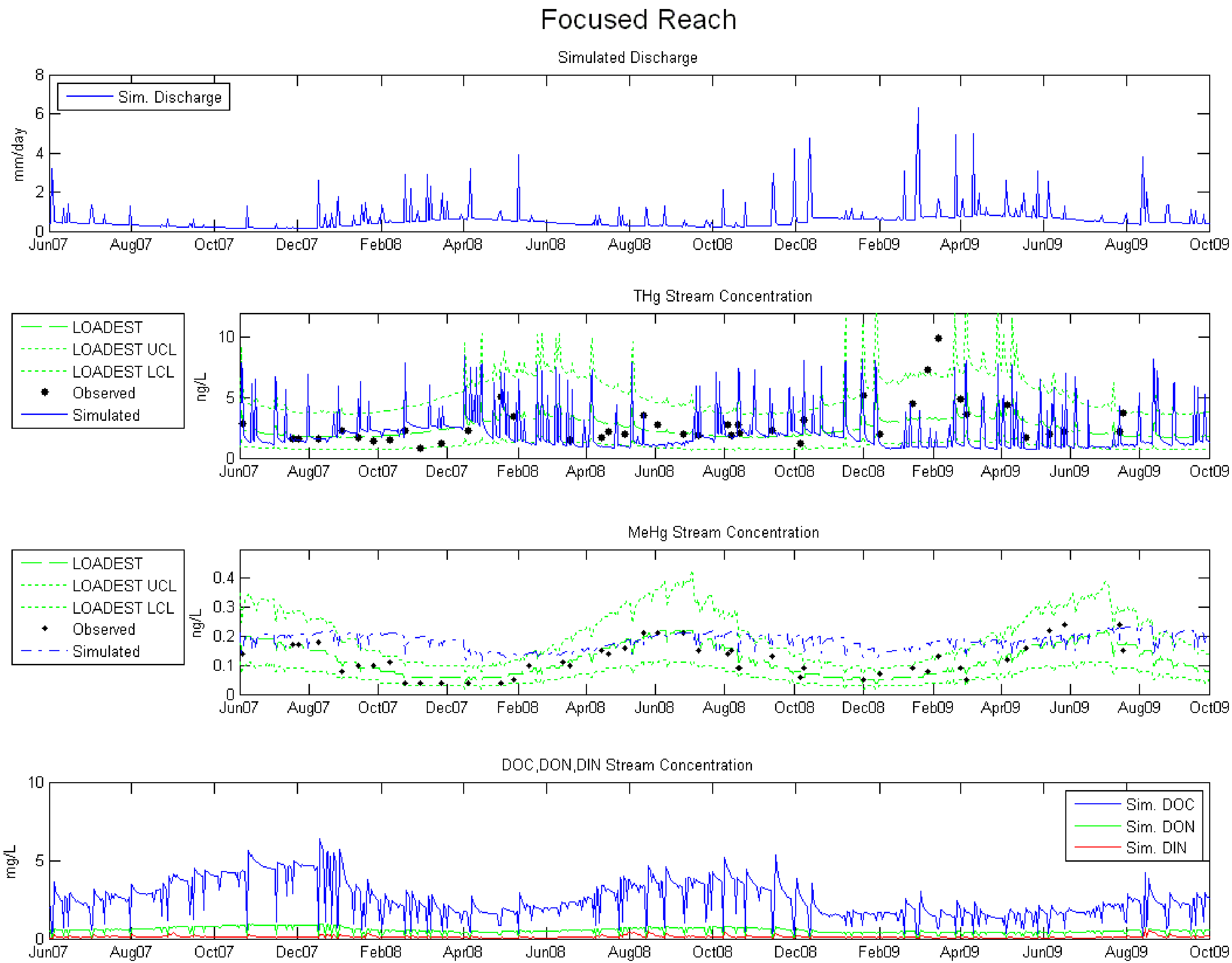
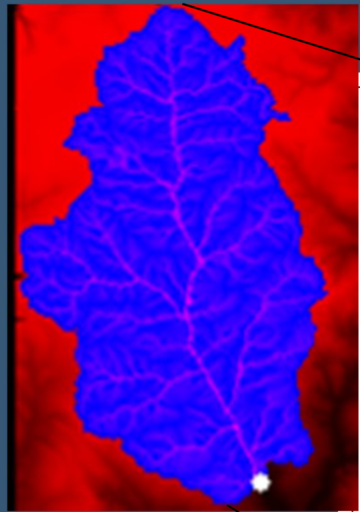


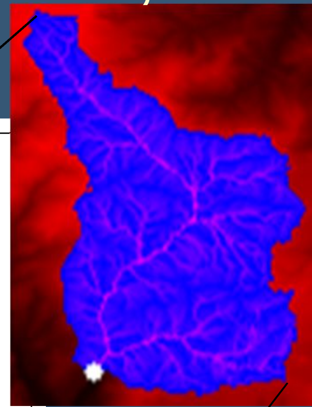
Focused Reach
Simulated Discharge
Sim. Discharge
mm/day
0
2
4
6
8
Jun07
Aug07
Oct07
Dec07
Feb08
Apr08
Jun08
Aug08
Oct08
Dec08
Feb09
Apr09
Jun09
Aug09
Oct09
THg Stream Concentration
LOADEST
LOADEST UCL
LOADEST LCL
Observed
Simulated
ng/L
0
5
10
MeHg Stream Concentration
0
0.1
0.2
0.3
0.4
DOC,DON,DIN Stream Concentration
Sim. DOC
Sim. DON
Sim. DIN
mg/L

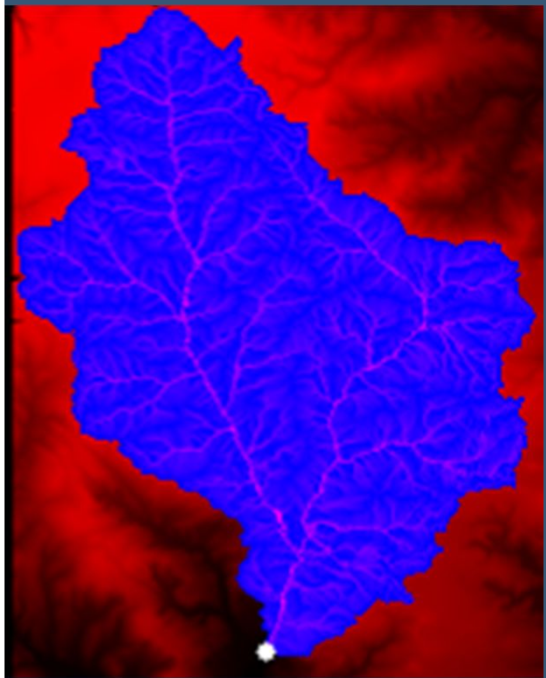
McTier Creek Watershed Modeling: VELMA

Monetta Gauge, 28 km^2

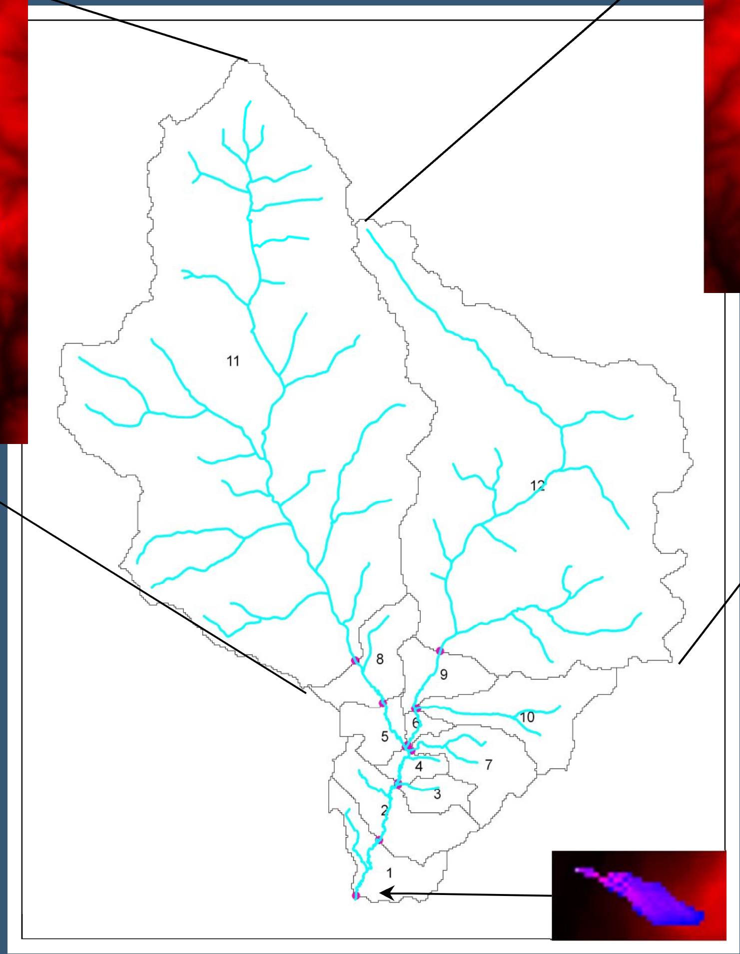


Gully Creek, 25 km^2





New Holland, 79.4 km^2

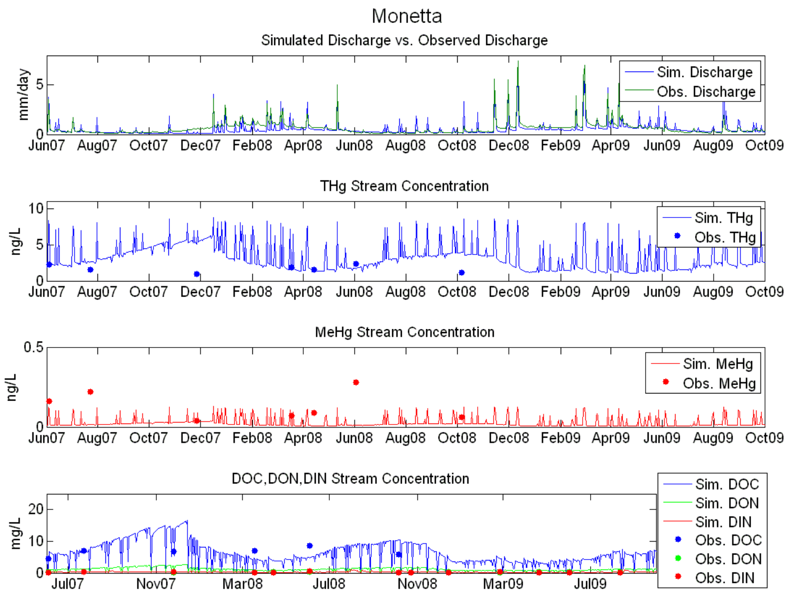


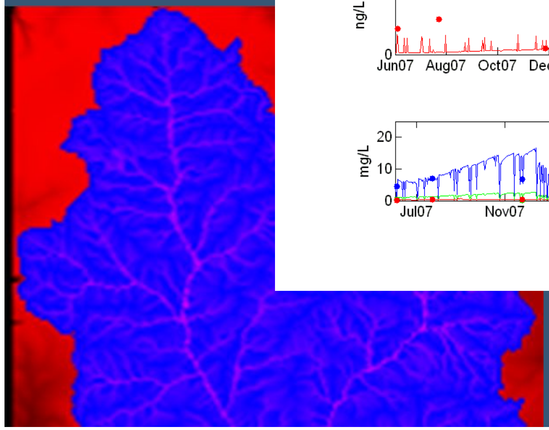
Focused Reach, 0.1 km^2

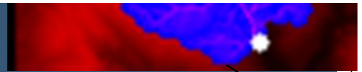
Mo... d Modeling:

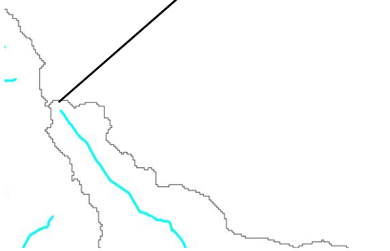
Mo...

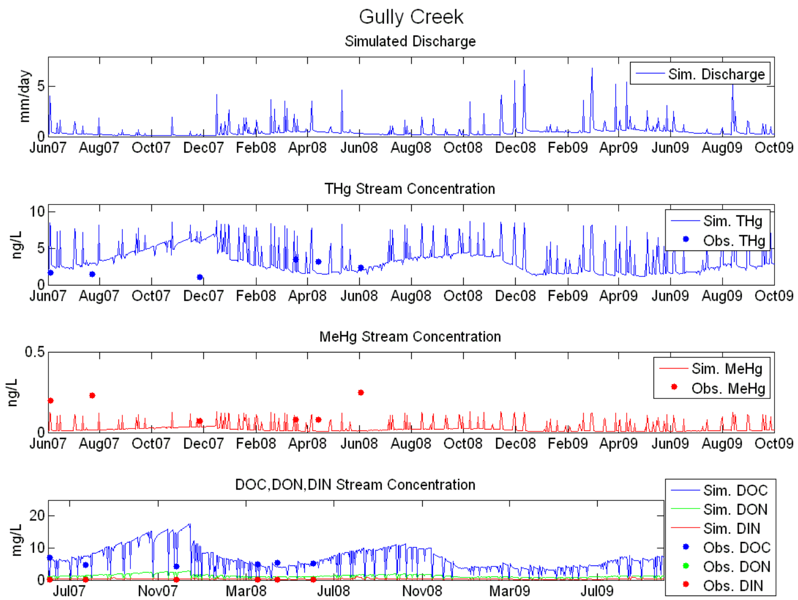
Gully Creek, 25 km^2

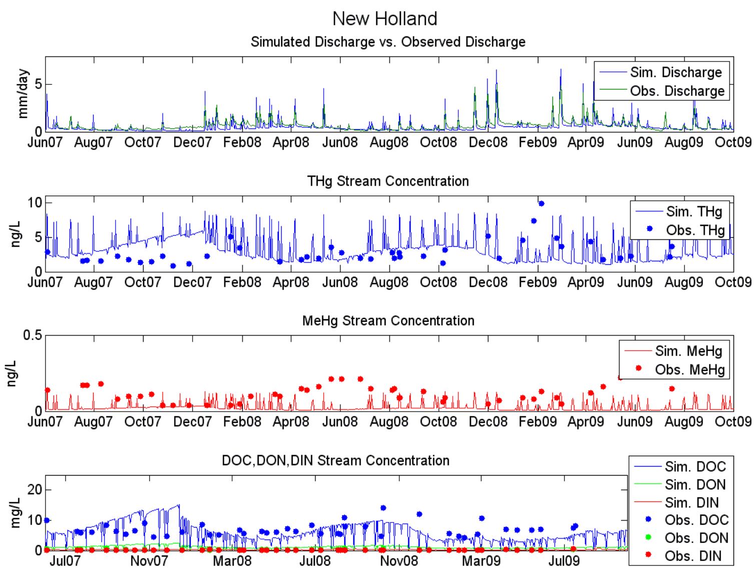












Summary

Combination of a field study and modeling efforts provides insight into biogeochemical cycling of mercury that neither could afford on its own

Comparison with observed and LOADEST values indicates THg stream concentrations are capture well in VELMA simulations

VELMA simulates MeHg stream concentrations well during part of the year, but over-predicts in late summer and early fall

Future Research

•VELMA simultaneously simulates

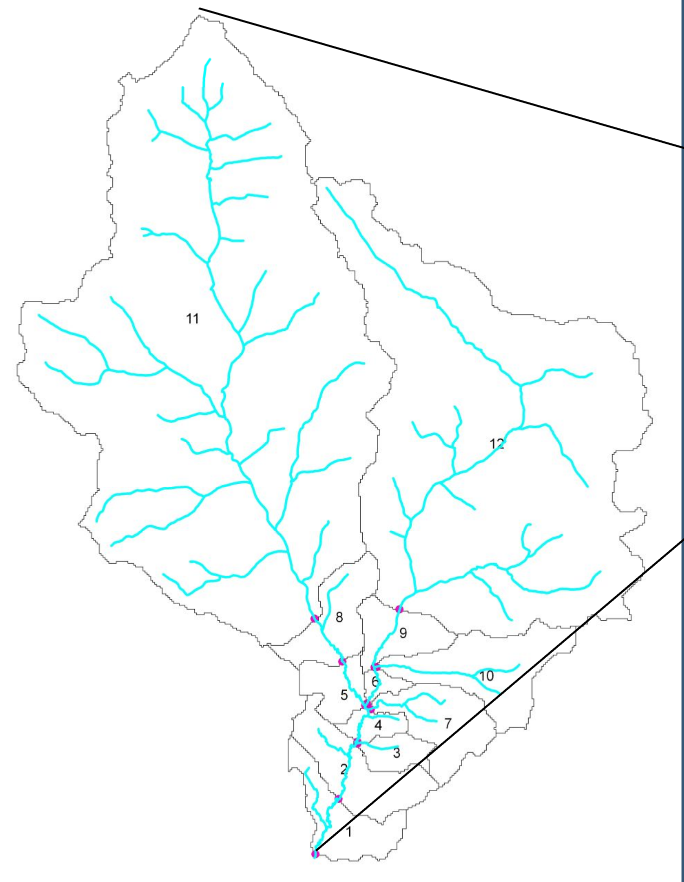
- DON (Dissolved Organic Nitrogen),
- DIN (Dissolved Inorganic Nitrogen),
- and DOC (Dissolved Organic Carbon)

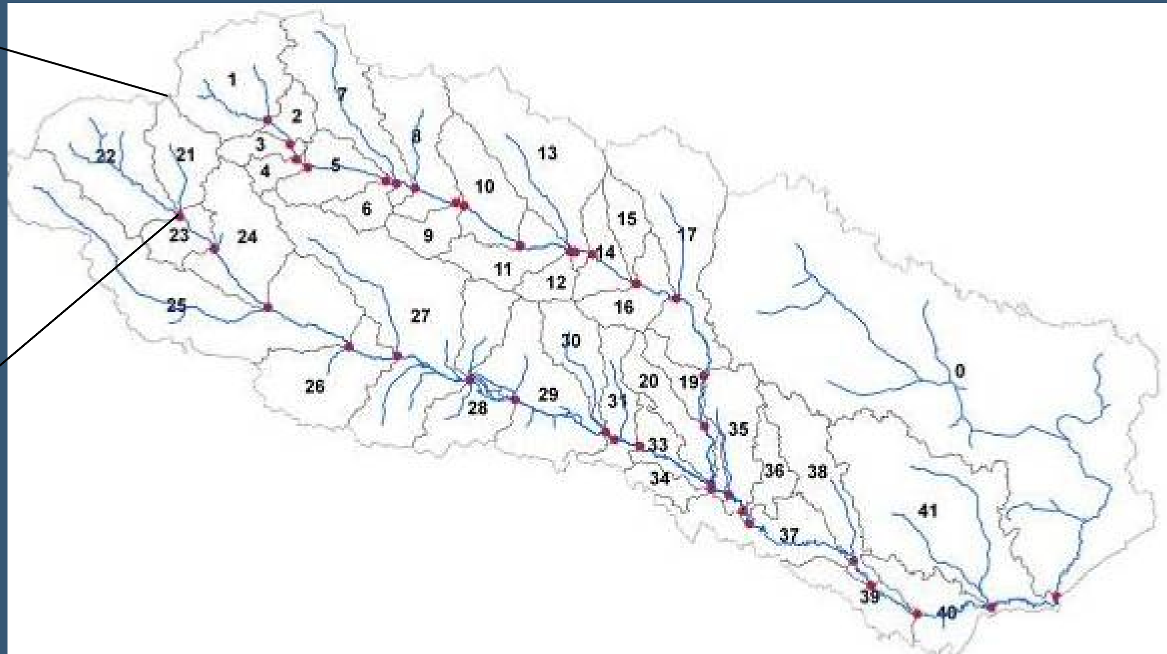
• We can investigate their importance and their feasible impacts on Hg exposure concentrations (land use change, climate change)

• Linking VELMA to WASP to BASS to simulate fish tissue concentrations to link atmospheric Hg deposition to human and wildlife exposure (source to receptor)

• Continual improvements on VELMA (land use, land cover)

Future Research





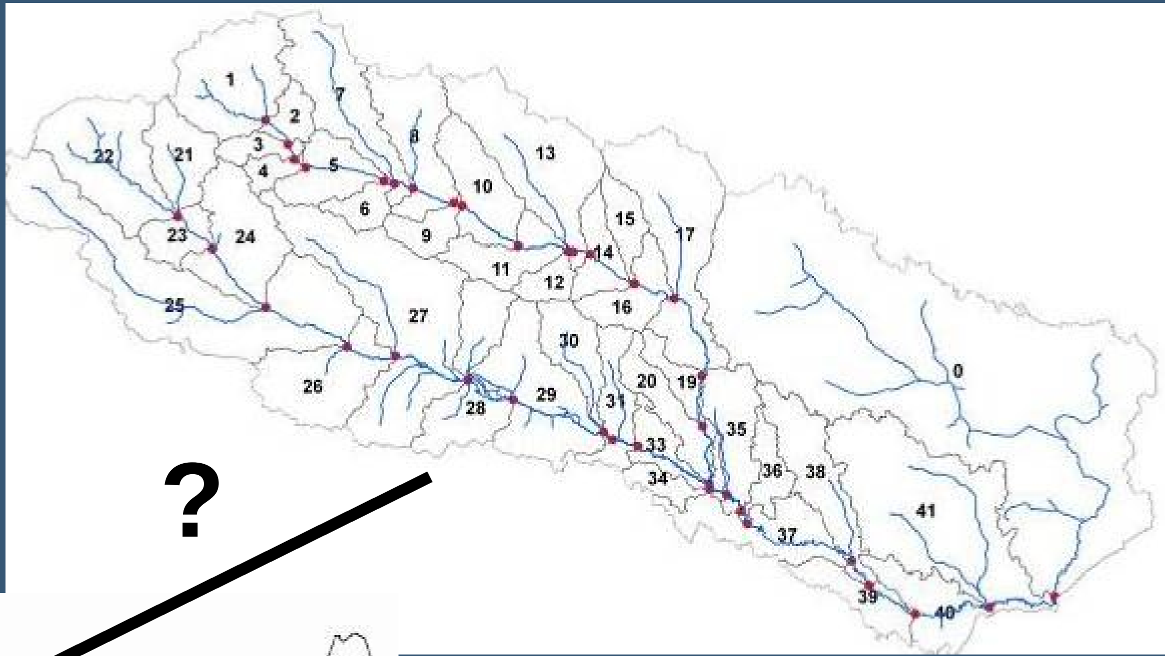
Using focused reach study to inform McTier Creek (HUC12),

Can we then use McTier Creek to inform regional scale?

→South Fork Edisto (HUC8)?
→North **and** South Fork Edisto?

Future Research

How far can we zoom out?



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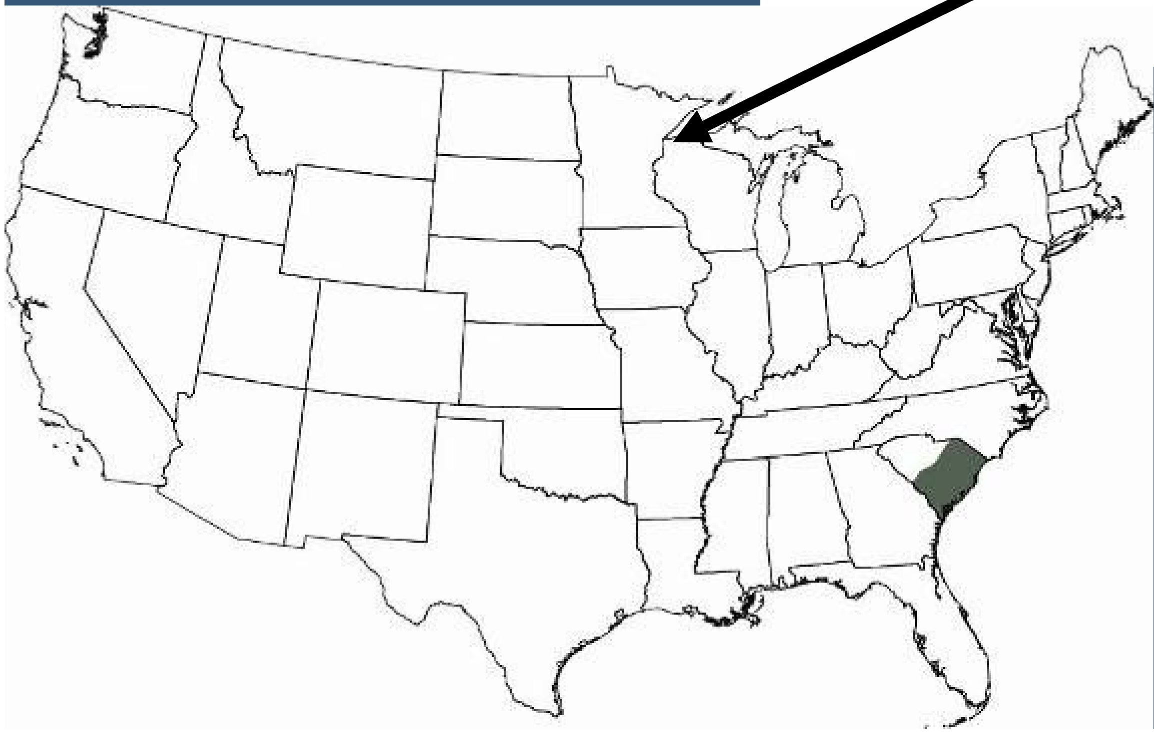
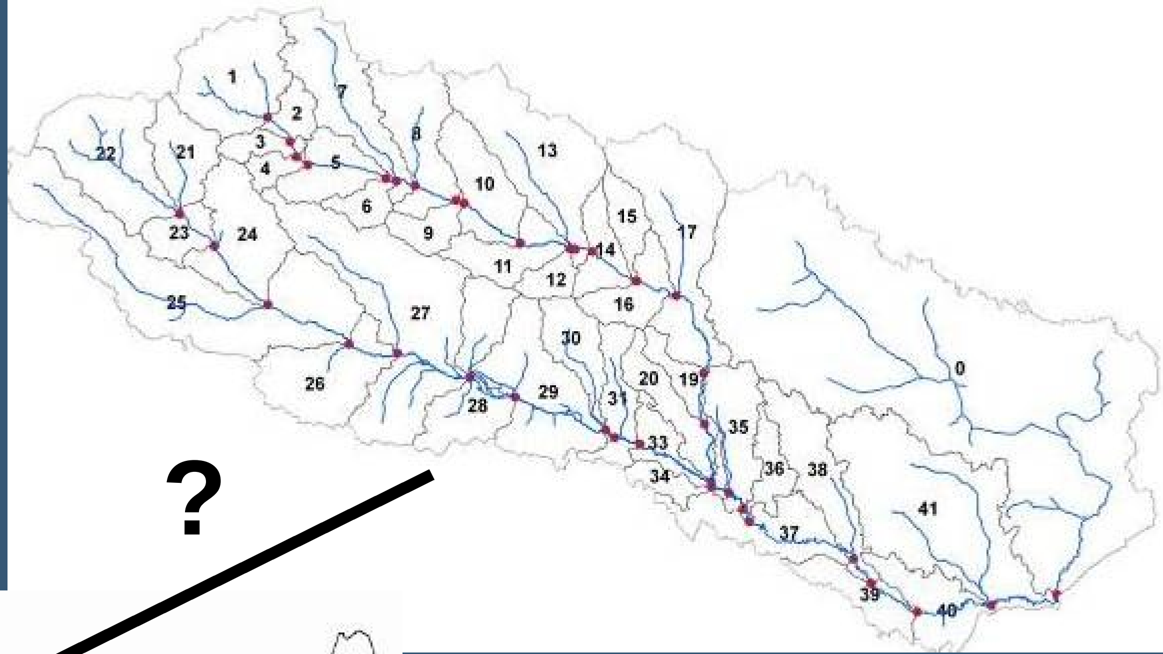


South Carolina Coastal Plain

Future Research

How far can we zoom out?



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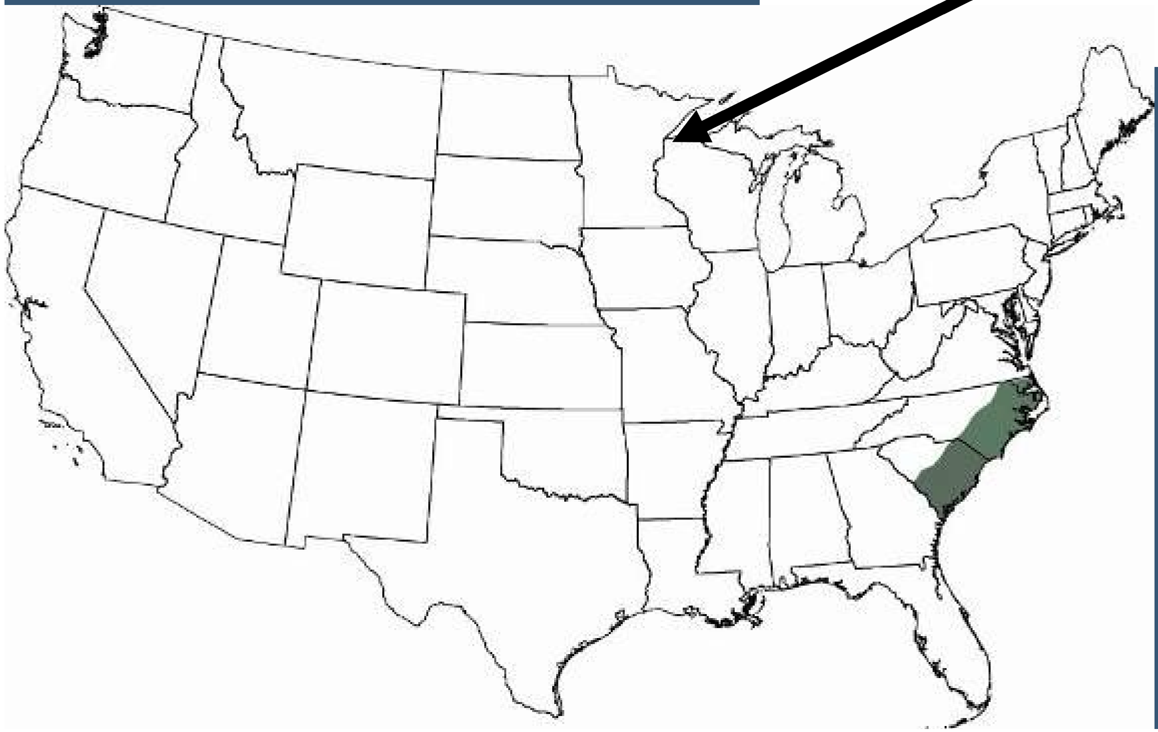
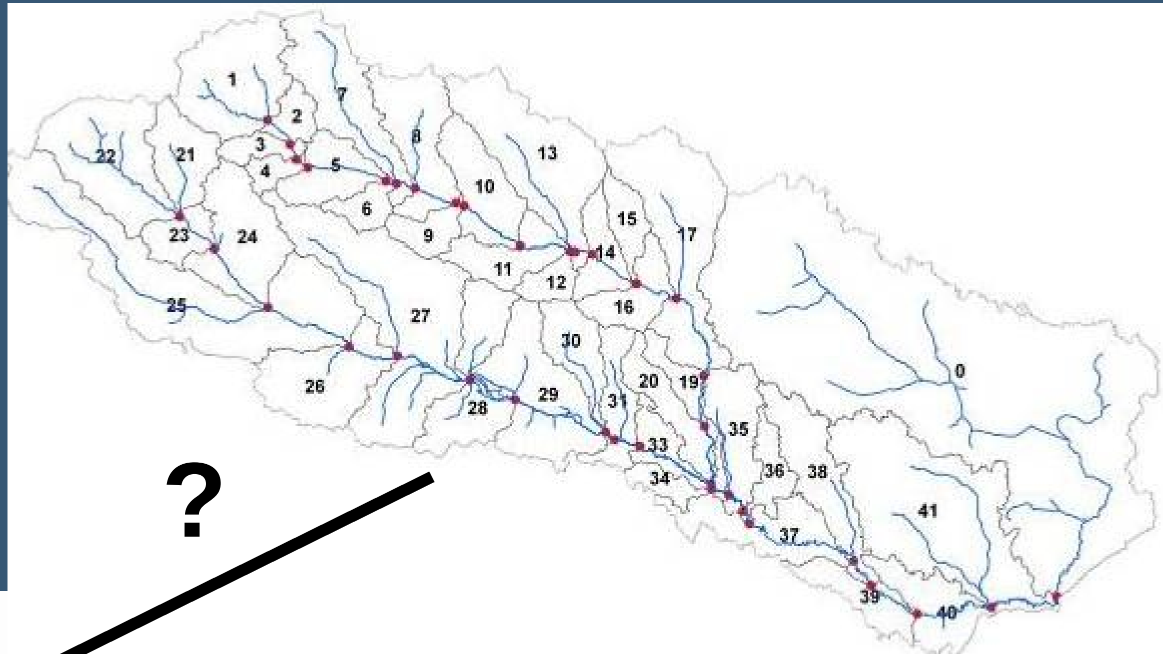


Coastal Plain of the Carolinas

Future Research

How far can we zoom out?



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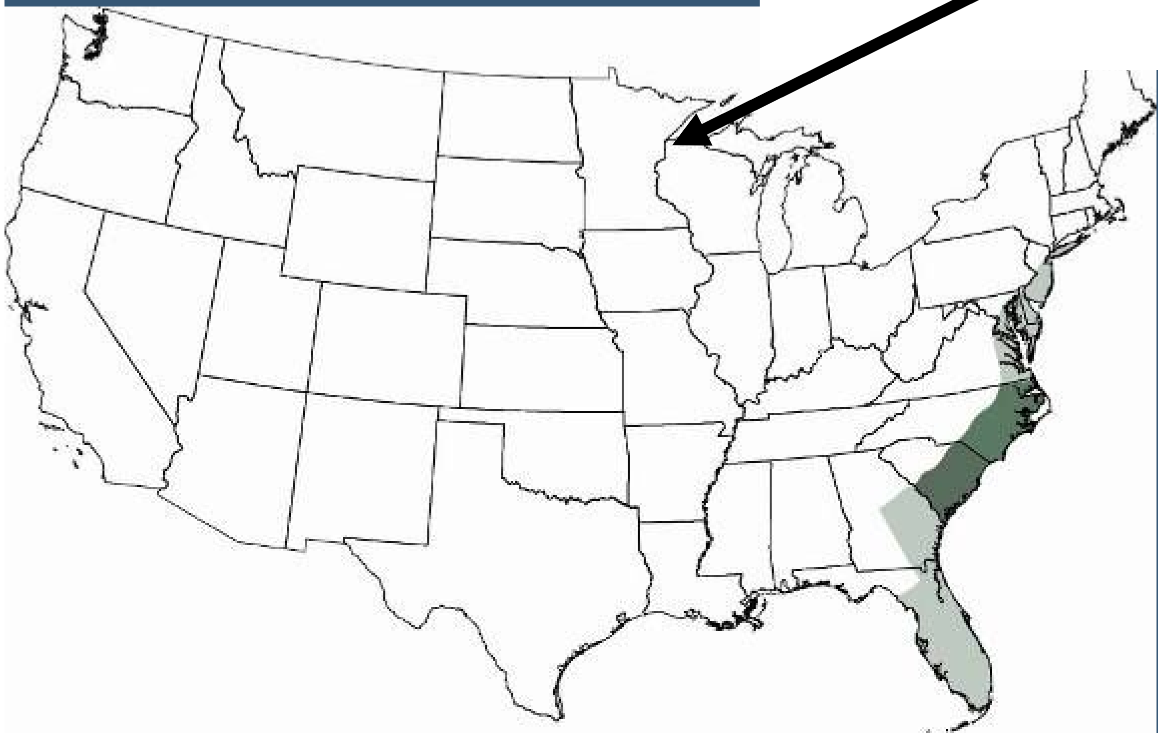
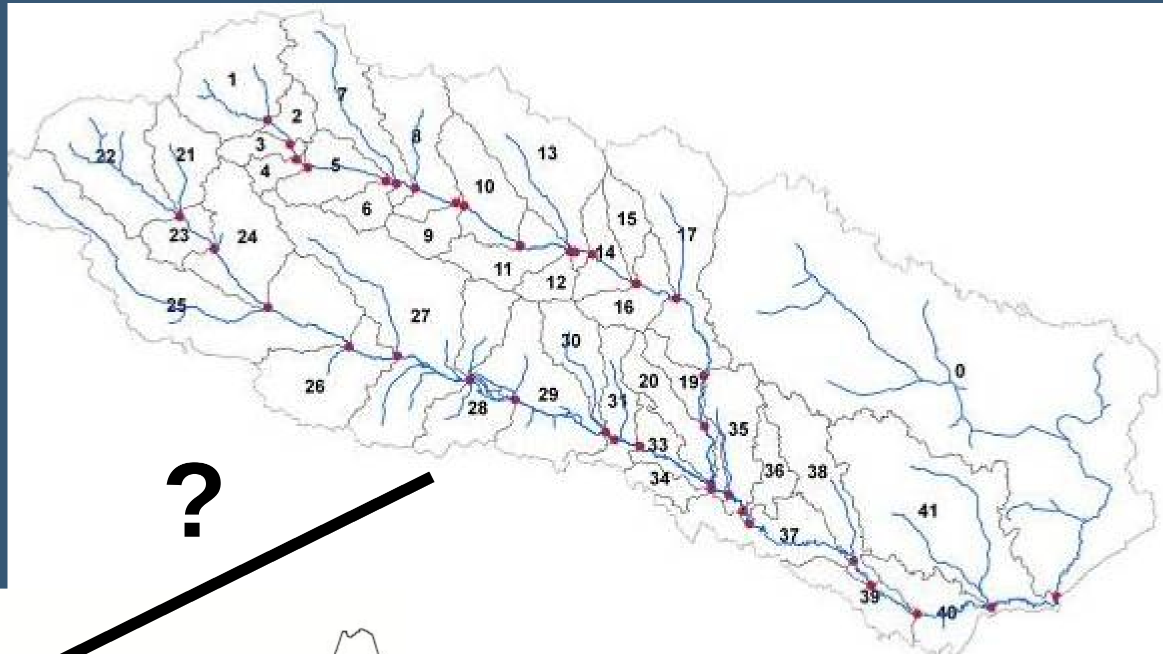


Atlantic Coastal Plain

Future Research

How far can we zoom out?



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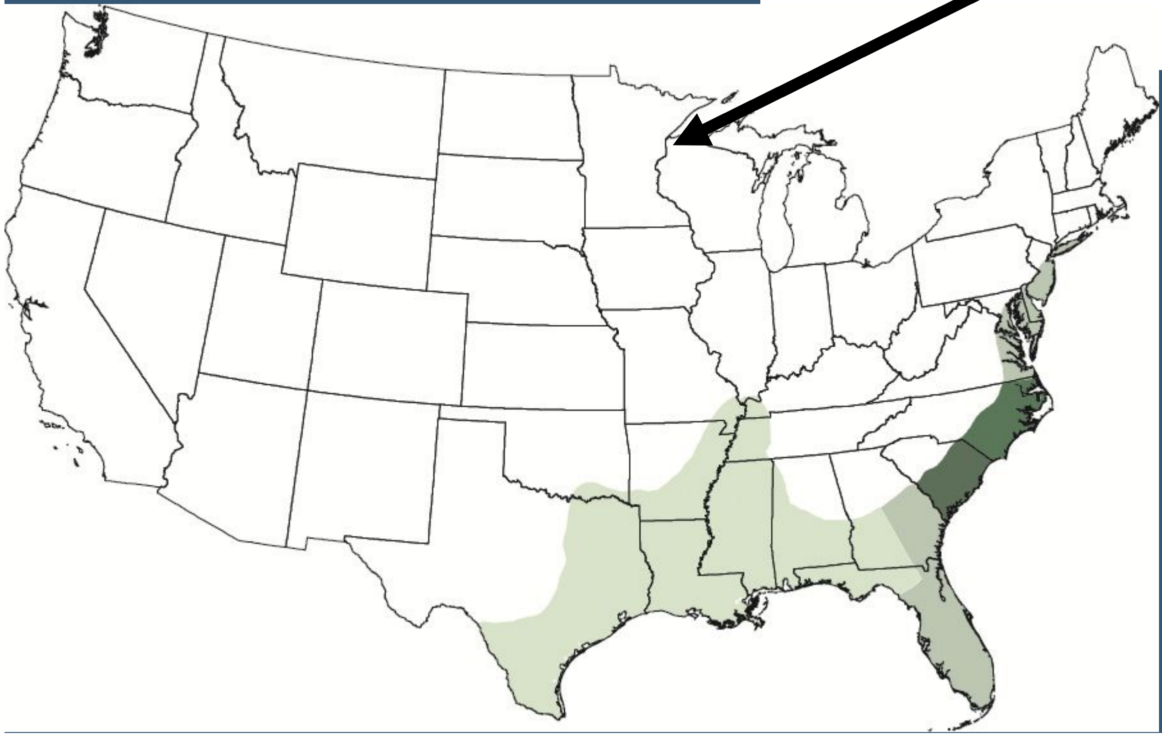

Coastal Plain